Spin-Triplet Superconductivity Induced by Ferromagnetic Fluctuations in UCoGe(Digest_要約)

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Summary of thesis: Spin-Triplet Superconductivity Induced by Ferromagnetic Fluctuations in UCoGe

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Identification of pairing mechanism leading to the unconventional superconductivity is one of the most challenging issues in condensed-matter physics. As the electron-phonon interaction in the conventional superconductivity, magnetic fluctuations have been proposed to mediate superconductivity, and considerable efforts have been made to unravel the relationship between magnetic fluctuations and superconductivity. Therefore the discovery of superconductivity in ferromagnet UGe_2 under pressure in 2000 had a great impact and provided a new system where we can investigate the relationship between ferromagnetic (FM) fluctuations and superconductivity. So far, four uranium FM superconductors have been reported: UGe_2, URhGe, UIr, and UCoGe.

In these FM superconductors, UCoGe is one of the most experimentally explored, because of the highest $T_{SC} \sim 0.8$ K and lowest $T_{Curie} \sim 3$ K at ambient pressure[1]. Although the crystal structure is three dimensional, magnetic properties possess strong Ising anisotropy with the *c* axis being the easy axis[2]. In addition, it is reported that the superconducting (SC) upper critical limiting field H_{c2} has also large anisotropy[2,3]; superconductivity survives with the external field as large as 15 T along the *a* and *b* axes, whereas along the *c* axis is as small as 0.5 T. This large H_{c2} along the *a* axis is suppressed with a steep angle dependence when the field was tilted slightly from the *a* axis toward the *c* axis[3]. In addition, the superconductivity becomes robust against the external field along the *b* axis when $\mu_0 H$ greater than 5 T is applied[3]. The observed characteristic H_{c2} behavior is one of the mysterious features of the superconductivity of UCoGe, and its origin would be related to the mechanism of the superconductivity. To clarify the relationship between ferromagnetism and superconductivity, we have done Nuclear Quadrupole Resonance (NQR) / Nuclear Magnetic Resonance (NMR) measurements on UCoGe.

The ^{59}Co NQR signal below 1 K indicates ferromagnetism throughout the sample volume, while the nuclear spin-lattice relaxation rate $1/T_1$ measured on the FM signal decreases below T_{SC} due to the opening of the SC gap, providing unambiguous evidence for the microscopic coexistence of ferro-

magnetism and superconductivity. Although ferromagnetism exists homogeneously throughout the sample, the superconductivity of UCoGe would be intrinsically inhomogeneous, which might be interpreted in terms of a Self Induced Vortex state[4,5].

From the angle-resolved NMR measurements we showed that longitudinal FM fluctuations along the *c* axis is dominant in UCoGe[6]. In addition, we found that this longitudinal FM fluctuations are well tuned by the external magnetic field; The magnetic field along the *c* axis $H||c$ suppresses the fluctuations drastically[7], while transverse field $H||b$ enhances the fluctuations. Interestingly this tunable FM fluctuations seem to couple to the superconductivity strongly since the anisotropy of the FM fluctuations[7] is well scaled to that of the superconductivity[3]. Combined with the theoretical model calculation, the longitudinal FM fluctuations are strongly suggested to be a SC pairing glue, concomitantly resolving the abovementioned puzzle of H_{c2}.

This scenario was supported by following Knight-shift measurements in the SC state. We found that ^{59}Co Knight shift for $H||a$ and b shows almost constant behavior below T_{SC}[8]. The observed Knight-shift results as well as unchanged spontaneous moments in the SC state can be reasonably interpreted with the scenario of spin-triplet superconductivity with band splitting where equal spin forms the pair with spin quantization axis parallel to the direction of spontaneous magnetization and the band splitting energy is larger than the SC gap energy.

Above experimental results strongly suggest that spin-triplet superconductivity mediated by the longitudinal FM fluctuations with large band splitting is realized in UCoGe

References

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